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Infrared nanoantenna couplers for plasmonic slot waveguide

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Abstract A slot plasmonic waveguide is promising solution as a replacement of electrical interconnects in the future optical integrated circuits. In this contribution we consider a set of compact solutions for coupling the infrared light from free space to the plasmonic slot waveguide. We systematically study various designs: dipole antennas outside the waveguide, antennas inside the waveguide and bow-tie antennas in the slots.

Plasmonics provides groundbreaking solutions for extreme light concentration [1], that allows subwavelength light guiding [2]. Among the most promising is a plasmonic slot waveguide [3] that simultaneously allows for subdiffraction mode confinement and reasonable propagation length of tens of micrometers. Moreover, metallic parts can serve as electrodes modulating the properties of the dielectric environment in the slot. From the other side, small size of the slot mode makes difficult to couple light from free space or an optical fiber into the plasmonic waveguide. Plasmonic nanoantennas, besides the applications for photodetectors [4], lasers [5] and light-emitting diodes [6] improvement, have been recently proposed as couplers to the plasmonic slot [7,8] and nanowire [9] waveguides.

In this contribution we consider compact nanoantenna based solutions for efficient coupling of infrared light from free space to the plasmonic slot waveguide. We systematically study various designs: dipole antennas outside the waveguide, antennas inside the waveguide and bow-tie antennas in the slots (see Fig. 1).

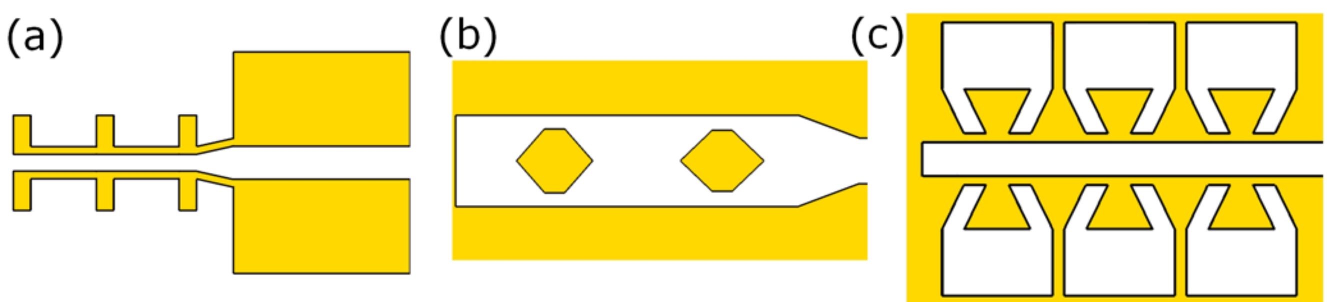

Figure 1. Sketch of the regarded nanoantenna coupler designs, white slits are air; (a) dipole antennas outside a waveguide, (b) antennas inside a waveguide, (c) bow-tie antennas in slots.

The dipole antenna (Fig. 1(a)) and bow-tie antenna (Fig. 1(c)) are placed externally to the gap. They excite plasmons in the gap, which then propagate in the slot waveguide. The antennas inside the waveguide (Fig. 1(b)) act in a similar manner but from the inside of the slot waveguide. Connecting several antennas gives an opportunity to capture radiation from larger area.

Simulation of the nanoantenna couplers is done in the CST Microwave Studio. The antennas are excited with a beam, which is Gaussian in one direction and homogeneous in the other (analogue of a beam focused with a cylindrical lens). For characterization of the nanocoupler performance we define antenna's figure of merit (AFOM) equal to the product of the coupling efficiency and the excitation spot area. AFOM is related to an effective area from which the antenna gain signal.

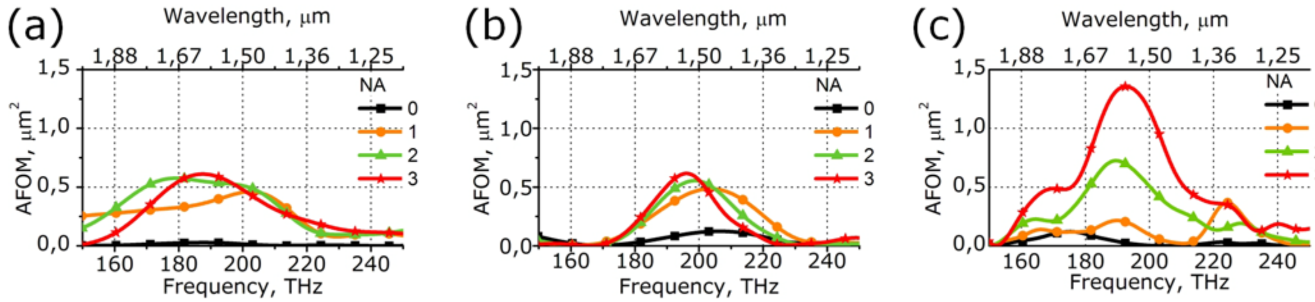

Figure 2. Antenna's figure of merit (AFOM) for (a) dipole antennas outside a waveguide, (b) antennas inside a waveguide and (c) bow-tie antennas in slots. The results are shown for different number of antennas: zero (black squares), one (orange circles), two (green triangles) and three (red stars)

Dipole antennas outside the waveguide and antennas inside the waveguide show similar AFOM (see Fig. 2(a) and (b)). Bow-tie antennas in the slot show better performance with AFOM reaching 1.4 μm^2 for three connected antennas (see Fig. 2(c)). In all cases several connected antennas allow for more efficient coupling into the slot waveguide. However, fast saturation effects are observed for the first two cases.

During the presentation the results of fabrication and experimental characterization will be shown. Pros and cons of each system will be reported.

The nanoantenna based couplers can provide a compact and efficient interface between optical fibers and plasmonic slot waveguides as well as directive in-chip communication systems.

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REFERENCES

1. J. A. Schuller, E. S. Barnard, W. Cai, Y. C. Jun, J. S. White, and M. L. Brongersma, "Plasmonics for extreme light concentration and manipulation," *Nature Materials* **9**, 193-204 (2010).
2. S. I. Bozhevolnyi, *Plasmonic Nanoguides and Circuits* (Pan Stanford, 2008).
3. L. Liu, Z. Han, and S. He, "Novel surface plasmon waveguide for high integration.," *Opt. Express* **13**, 6645-50 (2005).
4. M. W. Knight, H. Sobhani, P. Nordlander, and N. J. Halas, "Photodetection with Active Optical Antennas," *Science* **332**, 702-704 (2011).
5. N. Yu, R. Blanchard, J. Fan, Q. J. Wang, C. Pflügl, L. Diehl, T. Edamura, M. Yamanishi, H. Kan, and F. Capasso, "Quantum cascade lasers with integrated plasmonic antenna-array collimators," *Opt. Express* **16**, 19447-19461 (2008).
6. C.-Y. Cho, M.-K. Kwon, S.-J. Lee, S.-H. Han, J.-W. Kang, S.-E. Kang, D.-Y. Lee, and S.-J. Park, "Surface plasmon-enhanced light-emitting diodes using silver nanoparticles embedded in p-GaN.," *Nanotechnology* **21**, 205201 (2010).
7. J. Wen, S. Romanov, and U. Peschel, "Excitation of plasmonic gap waveguides by nanoantennas," *Opt. Express* **17**, 5925-5932 (2009).
8. J. Huang, T. Feichtner, P. Biagioni, and B. Hecht, "Impedance matching and emission properties of nanoantennas in an optical nanocircuit," *Nano Letters* **9**, 1897-1902 (2009).
9. Z. Fang, L. Fan, C. Lin, D. Zhang, A. J. Meixner, and X. Zhu, "Plasmonic coupling of bow tie antennas with Ag nanowire," *Nano Letters* **11**, 1676-1680 (2011).